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The development of precision aneroids - interim report

by

R. Frith

(Meteorological Office)

AIR MINISTRY

METEOROLOGICAL RESEARCH COMMITTEE

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Introduction

Late in 1956 the Meteorological Office received three aneroids (G.1, G.2 and G.3) made to our Specification of Requirements No. 429 (General Purpose Precision Aneroid Barometer) and two aneroids (H.1 and H.2) made to our Specification No. 430 (High Precision Aneroid), all made by the same firm.

The instruments were not tested for robustness but in all other respects, as far as could be judged, they satisfied the requirements of the Specification. The robustness test (Clause 11 in the Specification) has not been made because the instruments are so heavy that a quite unreasonably large "strong wooden crate" would be required to give the protection needed to pass this test. The makers state that this defect could be overcome in future by building the mechanism into a light fabricated case instead of the present, very heavy, cast iron case. For a period of six months these instruments have been read every working day and the readings compared against a mercury barometer (except that Aneroid H.2 was lent to Prestwick after four months for special work there). The readings have now been analysed and the results are presented and discussed. The results of a similar analysis made some years ago on an earlier High Precision Aneroid (B) made for us by the same maker and on a commercially available aneroid (A), made by a different maker are included for comparison.

The basic data

The aneroids were left undisturbed throughout the period. They were sheltered from the sun and were tapped before reading. Two mercury barometers were in the same room. These never differed between themselves by more than 0.3 mb and rarely by more than 0.2. One of the mercury barometers was chosen as the 'standard'.

As far as could be determined, none of the aneroids had any scale error - that is to say, the errors appeared to be the same at all points of the scale. The temperature error, over the range of temperatures experienced, was very small.

The differences (aneroid-mercury barometer) for every reading are shown in Figure 1, and the frequency distribution of these errors is shown in Table 1, (only the period up to the first "jump" is used for Aneroid B)*.

Long-term stability

Figure 2 shows the errors plotted as running means of 10. With the possible exception of G.3, all the new aneroids show a tendency to secular drift in the sense of positive errors increasing, as indicated by pecked lines. This is in the same sense as drifts caused by a gradually weakening spring;

/and

*Until the present series of tests, sudden and persistent changes of 'zero' of this type were found in all aneroids tested.

and in the opposite sense to that caused by a leaking capsule. Instrument A might show the same tendency but there is no sign of it in B.

This drift is large enough to be important where the aneroids could be checked only, say, once a year and where, at the same time, accuracies of 0.5 mb or better are needed.

Accuracy

The effect of secular drift can be reduced to negligible proportions by checks against an accurate barometer at intervals of about two months. Table 2 indicates the accuracy which would have been achieved during the test period if the instruments had been adjusted on the basis of spot checks every two months. In order to make the most of the available data, every (overlapping) group of 40 observations (approximately two months) was separately analysed. The table shows also the accuracy which would have been achieved if the adjustments had been based on the mean of five consecutive (daily) observations instead of a single reading.

Discussion

These results may be discussed in the light of known requirements. The most obvious requirement is for use at sea, both in Selected Ships and in Ocean Weather Ships. Aneroids used in Selected Ships could normally be checked against a mercury barometer on shore at least once every second month without difficulty but the check would probably have to be based on a single reading. If we assume that the performance at sea would be no worse than the performance under laboratory conditions (and this has to be verified) then Table 2 indicates that, with all save one of the aneroids tested, there would be very few errors greater than 0.5 mb. This accuracy is considered to be sufficient for ordinary synoptic purposes at sea. (It should be noted that, where the accuracy aimed at is ±0.5 mb, there was little to choose between the relatively inexpensive commerical Aneroid and the more expensive specially made instruments.)

A rather higher accuracy is desirable on Ocean Weather Ships. Aneroids on Ocean Weather Ships could be checked before every voyage on the basis of five (or even more) daily readings. Assuming, again, that the accuracy at sea is no worse than has been found during these tests, then a 90 per cent accuracy of better than ±0.3 mb would be achieved with all save G.2. One, but only one, of the High Precision Aneroids, has an accuracy very much better than that. Apart from this High Precision Aneroid, the cheaper commercial instrument appears to be just about as good as any of the others.

Conclusions

It seems likely that an available commercial aneroid would be suitable for routine use at sea both on Selected Ships (checked every second month or so) and on Ocean Weather Ships (checked before every voyage).

The performances of the new aneroids were variable. It does not appear worthwhile to have aneroids specially made for us unless we could be sure that they would be as good as H.1 (the only one which was significantly better than A). This matter is being discussed with the makers.

(Note. We are also having made, and delivery is expected at any time, an aneroid which uses an ordinary capsule but, instead of the usual delicate magnification system of levers or chains, uses a robust electronic contact device. This instrument will also be tested for stability and accuracy.)

/Table 1.

Table 1. Percentage frequency distribution of errors over a period of about six months

	Error (aneroid - mercury barometer) - mb																				Mean error
	−0.5	−0.4	−0.3	−0.2	−0.1	0	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9	1.0	1.1	1.2	1.3	1.4	1.5	
G.1									1	5	9	14	23	27	15	7						+0.75
G.2									1	2	0	2	8	8	12	14	16	14	13	8	3	+1.1
G.3						1	7	12	14	28	14	7	7	2								+0.4
H.1							2	6	8	23	27	25	8	1	1							+0.5
H.2									3	1	6	18	30	21	16	3	1					+0.75
A			2	8	12	18	15	20	10	5	6	3	1									+0.15
B	2	2	3	10	20	25	13	20	3	1	0	2										+0.0

/Table 2.

Table 2. Percentage number of observations with errors not greater than specified amounts when aneroids are checked against a mercury barometer once every two months.

	Errors not greater than			
	± 0.3	± 0.5	± 0.3	± 0.5
	(Check based on a single reading)		(Check based on mean of 5 consecutive readings)	
G.1	90	99	94	100
G.2	74	91	78	98
G.3	84	97	91	99
H.1	93	100	100	100
H.2	90	99	94	100
A	80	97	92	98
B	84	98	93	99

M.O. Specification No. 429
Issue 1.
October, 1954.

METEOROLOGICAL OFFICE, AIR MINISTRY

Specification of Requirements for General Purpose Precision Aneroid Barometer

A. Materials

The best material for tropical and Arctic use commercially available for the purpose shall be used. Wherever possible, metals used shall be non-corrosive; if corrosive materials are used they shall, wherever possible, be adequately protected from corrosion by plating, lacquer, baked enamel, or other suitable covering or finish. Finishes which will crack, chip or peel under normal usage and ageing, or when subjected to changes of temperature and humidity, shall not be employed. Wear surfaces of gear teeth, pivots, bearing faces, etc. which cannot be protected with finishes shall be made of a material which will not appreciably tarnish or form oxydisation films.

B. Construction

1. The instrument shall be suitable for use at sea and in the field and it shall not be affected by the sort of vibration and movement experienced on a ship. It shall be sufficiently robust to withstand all ordinary transit risks when packed in a transit case (which shall be supplied with the instrument).

2. Means shall be provided for mounting the instrument vertically on a panel.

3. The dial shall cover the range of at least 930 - 1055 mb. and shall be graduated every millibar.

4. The distance between graduation marks shall be not less than .04 in.

5. The face of the dial shall be white, or matt silver.

6. The width of the pointer at the end extending over the graduations shall be not wider than 0.01".

7. There shall be some anti-parallax device.

8. The readings at any point shall not differ by more than 0.5 millibar when the instrument is used in a horizontal or in any vertical position.

9. A screw adjustment shall be provided, for setting the instrument, and it shall be possible to set the instrument accurately to 0.3 millibar. It shall be possible to make this adjustment whilst the instrument is mounted vertically on a panel.

10. The case of the instrument shall be airtight and fitted with a static connection in the side of the case. It should be possible to close this static connection.

11. With the static connection open the instrument shall be capable of withstanding pressures of 500 millibars and 1200 millibars without damage or change of calibration.

C. Accuracy

Random errors shall not exceed 0.5 millibar. (This includes hysteresis). Calibration (scale) errors shall not exceed 0.5 millibar.

/D.

D. Temperature Errors

The instrument shall be compensated for temperature: the reading at any point shall not change by more than 0.5 millibar for a change of temperature of 20 degrees C.

E. Drift

During the course of a year the scale error at any point shall not change by more than 1.0 mb.

Note

No relaxation of Clauses A, B.1, B.2, B.3, B.9, B.11, C and E can be tolerated. Manufacturers may, if they wish, quote for instruments not satisfying B.4, B.5, B.6, B.7, B.8, B.10, and D, but the extent to which these clauses will not be met must be stated in the quotation.

F. Tests

1. Visual and mechanical inspection

The instrument will be given a visual and mechanical inspection to determine the quality of materials, workmanship and general compliance with the requirements of this specification.

2. Vibration

There shall be no change in the reading when the instrument is subjected to vibration similar to that experienced on board ship.

3. Pressure seal

With the static connection closed and pressure reduced to 500 mb. the indicated pressure shall not change by more than 1 millibar in 10 minutes.

4. Calibration

The instrument will be calibrated in a pressure chamber at a temperature of about 20°C. The error at any point shall not exceed 1.0 millibar. During this calibration the pressure shall be changed at a rate not exceeding 10 millibars per minute and shall be held constant for at least one minute before any reading is taken. Readings shall be taken at about 10 millibar intervals over the whole range of the barometer.

5. Looseness and Backlash

The pressure shall be decreased from atmospheric to 930 mb. in 10 millibar steps and read at each step. The process shall be repeated for increasing pressure to 1050 mb. and then decreased again to atmospheric. The average difference in reading for increasing and decreasing pressure shall not exceed 0.5 millibar and at no point exceed 1.0 millibar.

6. Movement

The movement of the indicating hand shall be noted in tests 4 and 5. When the pressure is changing uniformly the indicating hand shall move uniformly. Irregular motion of the indicating hand shall be a cause for rejection of the instrument.

7. Friction

The aneroid shall be held in the hand and read without jarring or rotating, the instrument shall then be slowly and carefully lowered 3 feet. There shall be a perceptible movement of the indicating hand. The barometer shall then be raised 3 feet. There shall be a perceptible movement of the indicating hand.

8. Random Errors

The test specified in section 4 shall be repeated. The mean error shall not differ from the mean error obtained from the original calibration by more than 0.5 millibar and the difference shall not exceed 1.0 millibar at any point.

9. Change in error at 40°C.

The instrument shall be kept at 40°C. for at least 2 hours before testing. The test described in section 4 shall be carried out at a temperature of 40°C. The average error shall not differ from that found in the original calibration by more than 1.0 millibar.

10. Change in error at 0°C

The instrument shall be kept at 0°C. for at least 2 hours before testing. The test described in section 4 shall be carried out at a temperature of 0°C. The average error shall not differ from that found in the original calibration by more than 1.0 millibar.

11. Shock

The instrument, packed in its carrying case, and this, in turn, packed in a strong wooden crate and protected by wood wool (or similar) shall be dropped from a height of 3 feet on to a concrete floor on each corner, and each face in turn. The instrument shall then be tested as in sections 4 and 5: the mean change shall not exceed 0.5 millibar and the error shall not exceed 1.0 millibar at any point.

Note

Failure to pass this test will result in rejection of the instrument. The manufacturer will be notified when the test is to take place and he may, if he wishes, be represented at the test.

Annex 2 to M.R.P. 1077

M.O. Specification No. 430
Issue 1.
October, 1954

METEOROLOGICAL OFFICE, AIR MINISTRY

Specification of Requirements for High Precision Aneroid Barometers

A. Materials

The best material for tropical and Arctic use commercially available for the purpose shall be used. Wherever possible metals used shall be non-corrosive; if corrosive materials are used they shall, wherever possible, be adequately protected from corrosion by plating, lacquer, baked enamel, or other suitable covering or finish. Finishes which will crack, chip or peel under normal usage and ageing, or when subjected to changes of temperature and humidity, shall not be employed. Wear surfaces of gear teeth, pivots, bearing faces, etc. which cannot be protected with finishes shall be made of a material which will not appreciably tarnish or form oxydisation films.

B. Construction

1. The instrument shall be suitable for use at sea and in the field and it shall not be affected by the sort of vibration and movement experienced on a ship. It shall be sufficiently robust to withstand all ordinary transit risks when packed in a transit case (which shall be supplied with the instrument).

2. Means shall provided for mounting the instrument vertically on a panel.

3. The dial shall cover the range of at least 930 - 1055 mb. and shall be graduated every millibar.

4. The distance between graduation marks shall be not less than 0.1 in.

5. The face of the dial shall be white or matt silver. The graduation marks shall be black, clean-cut, clear and of uniform width between 0.004" and 0.007".

6. The width of the pointer at the end extending over the graduations shall be not wider than 0.01".

7. There shall be some anti-parallax device.

8. With the pressure held constant the readings shall not differ by more than 0.5 millibar when the instrument is used in a horizontal or in any vertical position.

9. A screw adjustment shall be provided for setting the instrument, and it shall be possible to set the instrument accurately to 0.1 millibar. It shall be possible to make this adjustment whilst the instrument is mounted vertically on a panel.

10. The case of the instrument shall be airtight and fitted with a static connection in the side of the case. It should be possible to close this static connection.

11. With the static connection open the instrument shall be capable of withstanding pressures of 500 millibars and 1200 millibars without damage or change of calibration

/C.

C. Accuracy

Random errors shall not exceed 0.2 millibar. (This includes hysteresis). Calibration (scale) errors shall not exceed 0.4 millibar.

D. Temperature Errors

The instrument shall be compensated for temperature: the reading at any point shall not change by more than 0.5 millibar for a change of temperature of 20 degrees C.

E. Drift

During the course of a year the scale error at any point shall not change by more than 0.5 mb.

Note

No relaxation of Clauses A, B.1, B.2, B.3, B.6, B.7, B.9, B.11, C and E can be tolerated. Manufacturers may, if they wish, quote for instruments not satisfying A.4, A.5, A.8, A.10 and D, but the extent to which these clauses will not be met must be stated in the quotation.

F. Tests

1. Visual and mechanical inspection

The instrument will be given a visual and mechanical inspection to determine the quality of materials, workmanship and general compliance with the requirements of this specification.

2. Vibration

There shall be no change in the reading when the instrument is subjected to vibration similar to that experienced on board ship.

3. Pressure seal

With the static connection closed and pressure reduced to 500 mb. the indicated pressure shall not change by more than 1 millibar in 10 minutes.

4. Calibration

The instrument will be calibrated in a pressure chamber at a temperature of about 20°C. The error at any point shall not exceed 0.6 millibar. During this calibration the pressure shall be changed at a rate not exceeding 10 millibars per minute and shall be held constant for at least one minute before any reading is taken. Readings shall be taken at about 10 millibar intervals over the whole range of the barometer.

5. Looseness and Backlash

The pressure shall be decreased from atmospheric to 930 mb. in 10 millibar steps and read at each step. The process shall be repeated for increasing pressure to 1050 mb. and then decreased again to atmospheric. The average difference in reading for increasing and decreasing pressure shall not exceed 0.2 millibar and at no point exceed 0.4 millibar.

6. Movement

The movement of the indicating hand shall be noted in tests 4 and 5. When the pressure is changing uniformly the indicating hand shall move uniformly. Irregular motion of the indicating hand shall be a cause for rejection of the instrument.

/7.

7. Friction

The aneroid shall be held in the hand and read; without jarring or rotating, the instrument shall then be slowly and carefully lowered 3 feet. There shall be a perceptible movement of the indicating hand. The barometer shall then be raised 3 ft. There shall be a perceptible movement of the indicating hand.

8. Random Errors

The test specified in section 4 shall be repeated. The mean error shall not differ from the mean error obtained from the original calibration by more then 0.2 millibar and the difference shall not exceed 0.4 millibar at any point.

9. Change in error at 40°C.

The instrument shall be kept at 40°C. for at least 2 hours before testing. The test described in section 4 shall be carried out at a temperature of 40°C. The average error shall not differ from that found in the original calibration by more than 0.5 millibar.

10. Change in error at 0°C.

The imstrument shall be kept at 0°C. for a least 2 hours before testing. The test described in section 4 shall be carried out at a temperature of 0°C. The average error shall not differ from that found in the original calibration by more than 0.5 millibar.

11. Shock

The instrument, packed in its carrying case and this, in turn, packed in a strong wooden crate and protected by wood wool (or similar) shall be dropped from a height of 3 feet on to a concrete floor on each corner, and each face in turn. The instrument shall then be tested as in sections 4 and 5: the mean change shall not exceed 0.2 millibar and the error shall not exceed 0.4 millibar at any point.

Note

Failure to pass this test will result in rejection of the instrument. The manufacturer will be notified when the test is to take place and he may, if he wishes, be represented at the test.

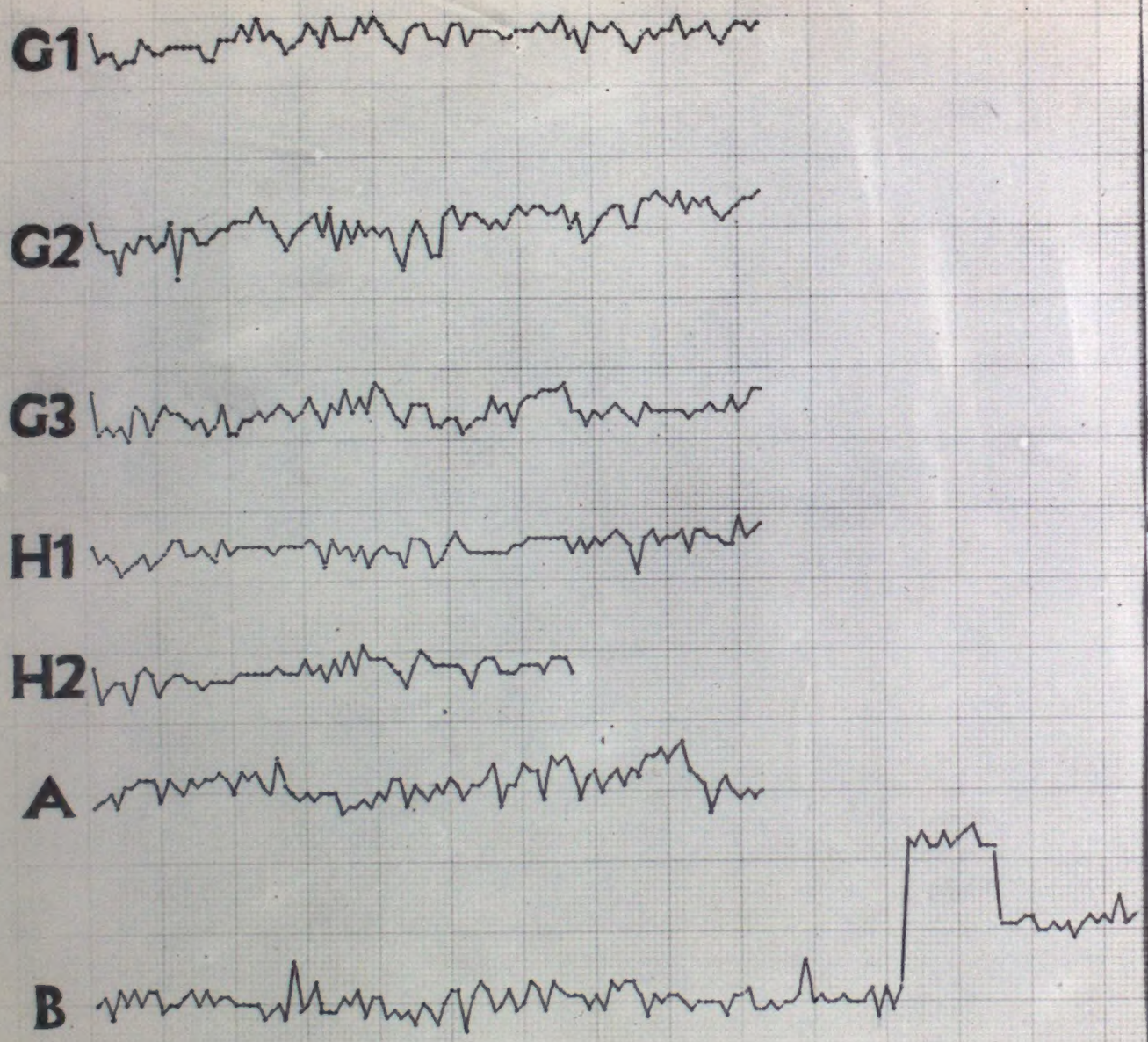

Fig. 1.

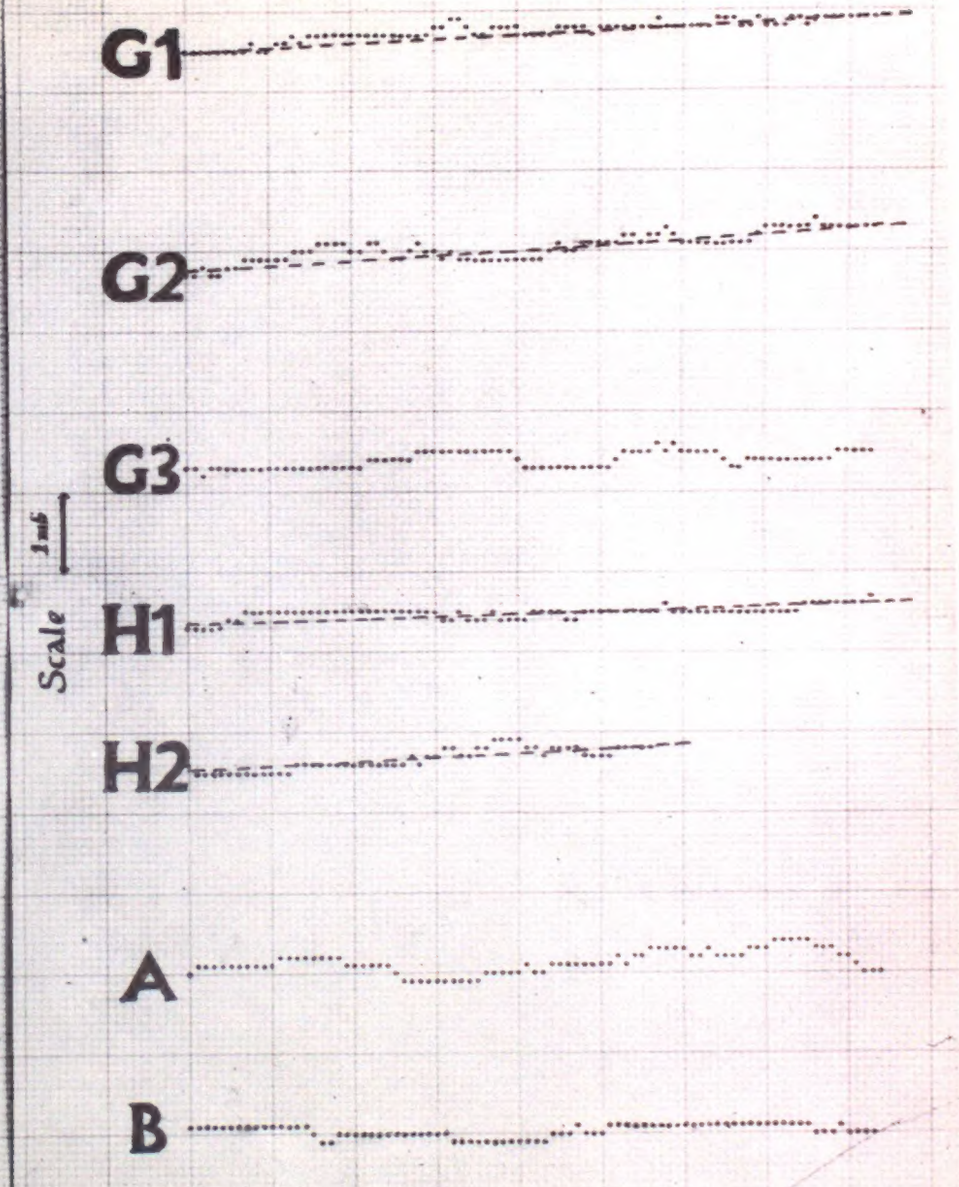

Fig. 2